Sensors and Actuators
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Lecture - 37
Illustration of fabricated Microfluidic Device for biochips with PDMS moulding

Hi, welcome to this particular lab class. In this lab class we will show it to you how to fabricate the microfluidic chip and this device will be used for as a biochip and with PDMS as a material and also we will show you how the moulding will work or how we can use mould for creating channels in PDMS. So, what exactly mould means, right?

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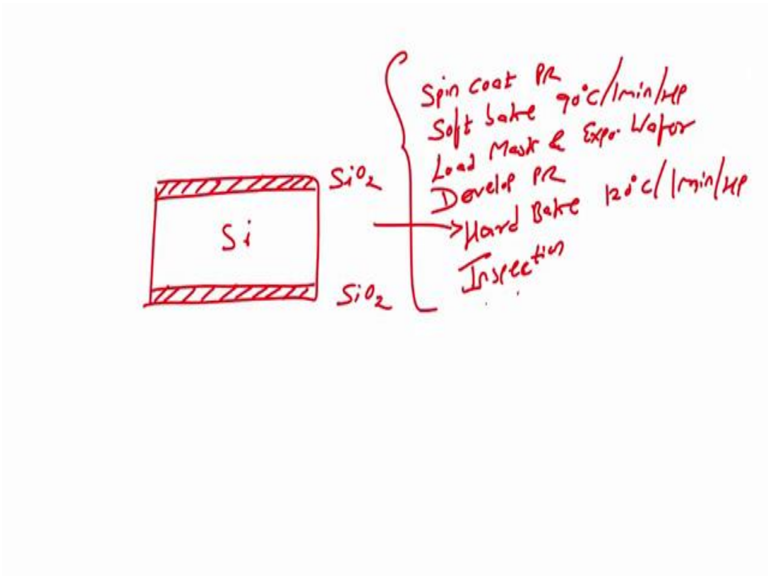

So, if you see the screen the, if I have silicon wafer right and if I grow silicon dioxide; let us say I am growing 1 micron of silicon dioxide.

Now you already know that if we use LPCVD then we can grow silicon dioxide on both the surfaces of silicon wafer, this is silicon dioxide, this silicon, this is silicon dioxide. Now if I go for photolithography, which is you know how to do right. Photolithography spin coat photo resist; then soft bake, soft bake is done as 90 degree Centigrade for 1 minute on hot plate. Next step is, you load the mask, load mask and expose the wafer, which is spin coated with photoresist.

Next step is you develop photoresist, after that you hard bake; hard bake is done at 120 degree Centigrade 1 minute on hot plate followed by inspection, inspection is done in using microscope, right. So, this is, these are the steps for your photolithography.

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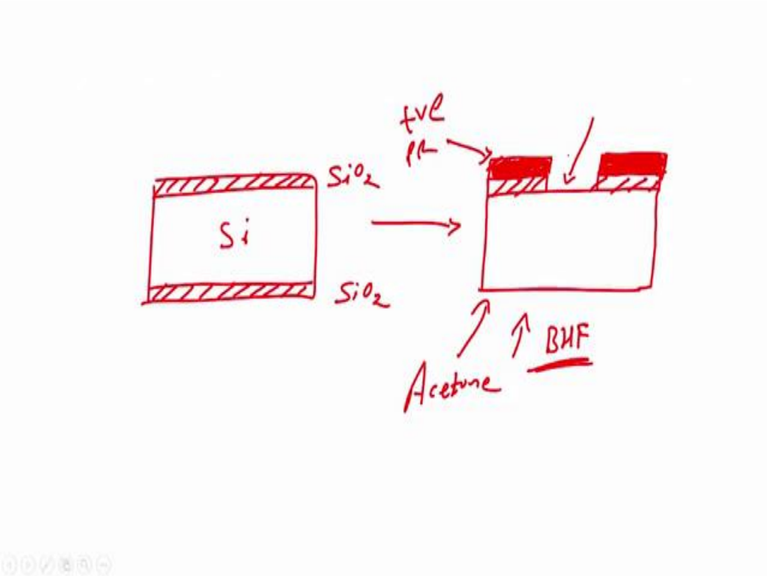

So, once I perform photolithography; what I will do here, is at I will create a window into silicon dioxide and then I will etch the silicon through that window.

What does it mean; if I perform photolithography, I will be creating a wafer, I will see this is an oxidize silicon wafer, and I will protect my photo resist in all the area except in the centre. So, this is my photo resist, as you can see there is a window, right. So, if I dip this wafer, this is my photo resist as a positive photo resist; if I dip this wafer in BHF, which is buffer hydrochloric acid. What will happen, my silicon dioxide will get etch, silicon dioxide will get etch.

In reality the silicon dioxide from back side will also get etch, because I do not have any protection on the back side. So, now, what will happen, you have etch silicon dioxide by dipping the wafer in BHF. After this, if I further dip this wafer in acetone; what will happen, the photo resist that is here will be etched or will be stripped off, acetone is a stripper for photo resist.

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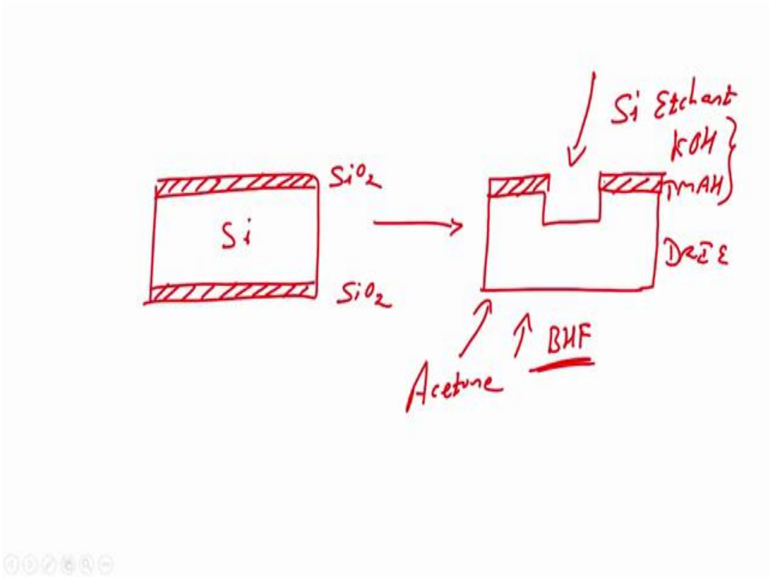

After this if I dip this wafer in silicon etchant, you know what are the silicon etchants? Silicon etchants are KOH potassium hydroxide, TMAH tetramethylammonium hydroxide, right; and you know the advantages and disadvantages of both the materials, also these are wet etching; but if I go for DRI, which is your dry etching is a deep reactive ion etching. So, if I etch silicon like this, all right by dipping the wafer in silicon etchant; what I have? I have a structure in an oxidized silicon wafer.

Now if I dip this wafer further into BHF, what will happen? If I dip this wafer further in BHF, then what will happen? This silicon dioxide will get etched right, and I will have silicon like this.

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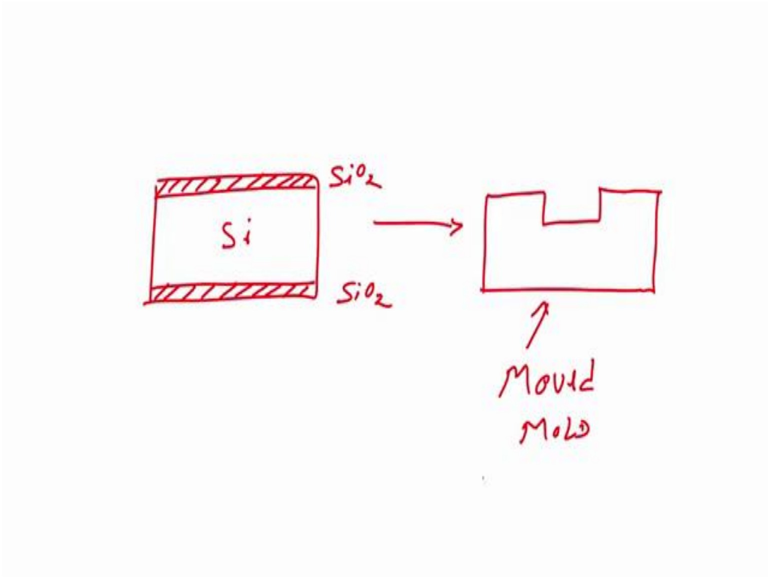

So, this silicon will act as a mould, people write in the different way; MOULD is also correct, MOLD is also correct, all right.

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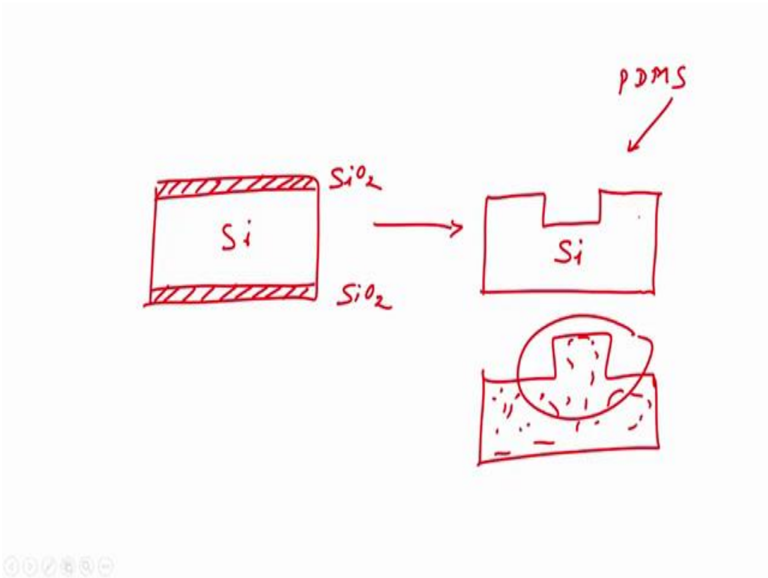

So, we have a mould, on which if I spin coat or if I pour PDMS, this is my PDMS and cure it; after curing I can strip it off, what will I have? I will have PDMS structure like this, right. So, after I strip it off, I can get back my mould; and I have already patterned my PDMS using this particular silicon mould.

Again if I pour, I can cure and I can create another structure. You can create as many structures as you want and that is why this is a part of your soft lithography as well. So, in this class, we will see the mould and how to create the; you know silicon PDMS moulding, how to fabricate microfluidic device with PDMS and the; I will invite now my student Anil to again show it to you, how to use this particular technique, right.

If have any questions feel free to ask; I will see you in the next class, where we will be actually showing it to you, how to compare microfluidic chip with and without PDMS moulding and what are their applications right. Till then, you take care; I will see you in next class, bye.

Welcome, today we start a series of short modules, where we show you different types of micro fabricated sensors that we have made in our lab and which we would like to show you as part of our course. The Idea is, I think in the previous modules you have seen readymade commercial sensors and the actuators and how they have been interface with micro controller broads like arduino etcetera.

Now today where we start as cities of modules, where we show you micro fabricated sensors, so these are not commercial sensors but we have fabricated in house using the different techniques of micro fabrication that you have learned as part of this course. Like photolithography, deposition like chemical vapour deposition, physical vapour deposition, lithography, etching all those methods; and then few packaging concepts like bonding, wire bonding, anodic bonding, oxide plasma bonding etcetera ok.

So, professor would have covered different types of substrates on which such sensors are made right. One type of substrate is silicon substrate, then you have glass substrate, then you have silicon on insulator substrate; so different types of substrates are there. On the substrates you make the sensors using different materials, like gold, platinum, molybdenum, titanium lot of materials are there which you can use to take these devices.

One very big class of sensors are the microfluidic devices, which allow for fluids, fluid flow in the micro scale like micro litres per minute; and also allows for sensors to be kept below the channel. So, it can be, it can become a dynamic system, you have a liquid; you can either have a static system or a dynamic system. Let us say you have a liquid, drops few drops of liquid and you want to analyse what is there inside the liquid.

The constituents of the liquid, you can either drop that liquid on to a static well which contains sensors below; or you can flow that liquid through a microfluidic channel with sensors below it.

The flow through a microfluidic channel it is a more dynamic system and it might emulate original real world conditions like blood flow in the body. So, that is why microfluidic systems are used.

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So, today I am showing you microfluidic device, you can see it in my hand. So, I have the microfluidic device in my hand correct. So, if you can see, if I tilt it like this, this thick membrane here forms a microfluidic channel.

This is PDMS polydimethylsiloxane; PDMS is the usual material that is used to make microfluidic channels but from a translational point of view, if you look at a product usually PDMS is not used, instead you use acrylic sheets or PMMA sheets; that is here next to me, these are acrylic sheets. So, these are acrylic sheets they are very thick right, see I am doing this, nothing happens to them. So, they are very robust. So, it can be handled in a real world practical scenario, you can make channels; you can see the white colour channels here, you can make channels by laser cutting these acrylic sheets.

That is one way of industrially making microfluidic chips but in a research domain usually PDMS is used because they are really easy to work with and fabricate ok.

Now if you look at this microfluidic chip, you have the electrodes, you can see gold pads here right; and there is a sensor at the bottom. So, you can see three sensors here. So, those are interdigitated electrodes and the conduct pads are coming here; these are gold interdigitated electrodes when the conduct pads are coming here ok.

Now, what we have done is, we have made microfluidic channels underneath this PDMS membrane and the channels are coming and sitting on top of this interdigitated electrodes. Then we will measure outside the microfluidic channel here, using these conduct pads. These pipes that you are seeing here, we can see these pipes, right. So, these pipes are the ports for inlet outlet, where you flow the liquid; these are varies fine 0.14 millimetre dia microfluidic tubes. They are called MFTs or microfluidic tubes, and they can be connected to a peristaltic pump or a series pump using microfluidic connectors or MFCs.

So, you have a pair of inlet ports. So, you connect one channel, one end of the peristaltic pump here, other end here; and you can flow a liquid through this and you can load samples through other channels. As a result you can keep flowing it, like you can flow blood; and if the blood contains let us say some chemical, you can capture that chemical in these electrodes, in this chambers; these are chambers here, I can capture these analytes in this chambers and then seize there electrical response.

So, this is a very simple way of making a microfluidic sensor ok. Here we are activating the flow of the liquid and sensing condense from the liquid. So, this is a sensor and actuator. So, this is a very useful biomedical application; there is a very useful biomedical application for this chip, because it is point of care. We just need a very small sample volumes, you can just put it and it will limitedly show you a result; if you connect it to a system that can measure impedance from this microfluidic chip.

So, this is how microfluidic chip looks like. This is from research point of view; if you want to make a product, a product will look like this. So, you can easily make it, you can handle it very in a very robust manner; it can be given to a lab technician, they can handle it, they can be trained very fast; and you can connect this a same connectors to this end and do the same work that is done by this.

Only limitation, if you look at it is, this PDMS is fabricated by pouring molten PDMS; I think you would have seen in the previous lecture. By pouring molten PDMS on to a silicon substrate that has the pattern, because the pattern is on a silicon substrate and you will use conventional micro fabrication techniques.

You can go to very fine dimensions for the channels; like up to we can even go to 100 micron channels, 200 micron channels.

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But these are mass produced microfluidic chip, these are all, these are also we have made in our lab. These are mass produced microfluidic chips; but because these are mass produced, they do not employee, they complex micro fabrication techniques, instead we use very fine laser cutting.

As a result we might not get 50 micron feature size but we can work with around 300-400 microns or 0.3, 0.4 mm which is good enough; if you look at it. So, it is a tradeoff between extreme accuracy and applicability or translatable nature of technology.

So, what you do is, you prove your technology with the most accuracy and sensitivity on a platform like this; because first of all you need to prove your technology, for that your sensitivity and accuracy has to be extremely high, and many times even more than what is required. Once you know your technology is working, you set benchmarks for your accuracy and sensitivity; you can move on to a platform like this, where you know that it is to have a slightly lesser accuracy and which you can tradeoff for manufacturability, this is easy to manufacture especially for mass manufacturing.

So, that is how you would make design decisions and that is how you make a technology, a research outcome translatable into a final product; that can be sold in the market and can change lives of people. So, that is micro fluid technology for you; like this we will see other sensors that we have fabricate in the lab, what are the method, what are the underlying principle of sensing, and how they are applied in a real life scenario.

Thank you, hope you found this useful.

Hi, in the previous short module, you saw how a microfluidic device is designed and what is the application and the, what is utility of using microfluidic technology? Today we will see a small extension of this in a two different microfluidic techniques. So, let us see the devices now. So, this is the microfluidic device that you already saw in the previous module, correct. So, the PDMS membrane was there, you had a glass light; I forgot to tell one thing, that is the glass light bonds to this PDMS membrane through oxygen plasma bonding.

What you do is, we have seen this in the oxygen plasma system in the lab. So, you activate the surface with oxygen plasma, you activate both the surfaces, and then you put them together, they will bond; that is another process ok. So, this sensor you have seen. So, without the PDMS membrane, I am showing you another sensor, ok. So, I am not sure whether you are able to see the features. So, let me just put with the tissue paper, ok.

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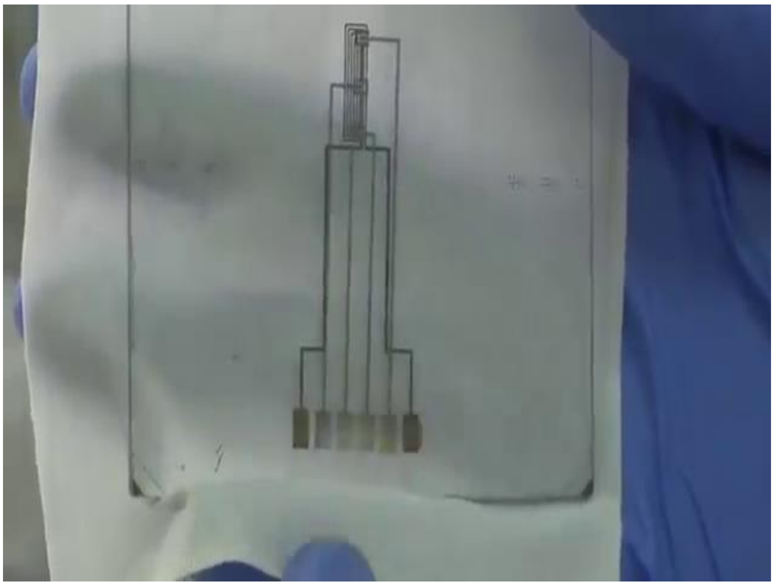

Now, I think you are able to see it. See if you see, this conduct pads are there, these are gold. And you can see three sensors like we saw a last time; but if you look closely there is another layer below it, ok. That is made of nichrome ok. So, this is a spiral structure as you can see it is continuously spiralling; this is actually a microheater. So, we have a microheater and electrons on top of it.

So, what is utility of such a structure is that, let us say you are working with live samples. Let us say you are trying to measure the impedance of live cells, live mammalian or cells live bacterial cells and you are continuously measuring it over a period of 1 day or 24 hours. Now you will be flowing the cells in their nutrient rich media, so that they can survive.

But then for cells to survive, they also need 37 degree Celsius temperature. So, how do you maintain that 37 degree Celsius temperature? For that, we need to have such microheaters. This microheater we will supply voltage this microheater and it will be heated up; and it can be controlled to be maintained at a particular temperature, let us say plus or minus 0.5 degree. So, between 29, 36.5 to 37.5 degree this heaters temperature can be maintained or even closer depending on how accurate we are control system is.

So, the heater will be maintained. So, the cells will be flowing, like in the previous microfluidic channel; but the cells will also feel the 37 degree Celsius reaches the internal body temperature. So, we are recreate the in vivo scenario in this microfluidic platform; as a result the whatever sensed data comes out, will be closer to an in vivo measurement, that is a over design ideology or philosophy.

So, you are flowing it at the flow rate which is equivalent to the flow rate of blood; then you are maintaining the inside body temperature which is 37 degree Celsius. Your channels are also designed to be mimicking the channel length of the blood vessels. So, your mechanical constructions or mechanical constraints of your blood vessel is meant, the mechanical flow constraints of your blood vessel is replicated in this microfluidic channels; as well as the thermal environment inside your body which is 37 degree Celsius is also recreated. How wonderful is that. That is the advantage of microfluidic technology.

So, you can recreate all these things; as a result of which your measurements from your sensing or your experiments will be as close as possible to the in vivo scenario. The truth remains, that you can never completely mimic your in vivo or what happens in your inside your body but you can get as close as possible, that is the pursuit of science. So, this way you are able to do that.

That is the advantage of microfluidic technology and that is the advantages of incorporating a micro sensor into these electrodes which you saw. So, this is I am adding one sophistication on to another of the previous design that we saw. So, that you understand the design process and how our requirement from real world comes down to a design in the sensor world.

That is the overall idea. I hope this idea came across to you in the very good manner and we will keep seeing these short modules.

Thank you.